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Highlights

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Effects of whole body vibration training on balance in adolescents with and without Down syndrome

M. Adoración Villarroya [a,b,*], Alejandro González-Agüero [a,c], Teresa Moros [b], Eva Gómez-Trullén [b,d], José A. Casajús [a,d]

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- Whole body vibration therapy was applied to youth with and without Down syndrome.
- Static balance was assessed before and after the 20 weeks of therapy.
- No effects in balance were observed in adolescents without Down syndrome.
- Improvements in balance under determined conditions were observed in the Down group.
- The importance of balance in functional activities makes promising these results.

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Effects of whole body vibration training on balance in adolescents with and without Down syndrome

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ABSTRACT

The present study aimed to determine whether a whole body vibration training program (WBV) is able to improve static standing balance in adolescents with and without Down syndrome (DS). Thirty adolescents with DS aged 11–20 years (DSG) and 27 adolescent, age/sex matched, without DS (CG) joined the study. Participants of each group were divided into two comparable groups, those who performed WVB (in DSG: VDSG; in CG: VCG) and those who did not perform WVB (in DSG: nVDSG; in CG: nVCG). Static-standing-balance under four conditions (C1: openeyes/fixed-foot-support; C2: closed-eyes/fixed-foot-support; C3: openeyes/compliant-foot-support; C4: closed-eyes/compliant-foot-support) was examine, before and after a 20-week WBV training program. For balance study, Postural-Parameters (PPs), based on center of pressure (COP) oscillations (anterior/posterior and medial/lateral COP excursion and COP mean velocity), and PPs ratios among the four conditions were calculated. After WBV training, no significant differences were found in any parameter in the VCG and nVCG and neither in the nVDSG, but there was a decrease of mean values in the analyzed PPs under C4, with significant differences in medial/lateral COP excursion and COP mean velocity, and a significant decrease in the ratio C4/C1 of the mean velocity in VDSG. Therefore, WBV training had positive effects in the balance of DS adolescents although only under specific conditions, with vision and somatosensory input altered. The positive results of this study are encouraging and open a wide field of research, looking for the most efficient program for this population.

1. Introduction

The ability to control balance of the body is an important prerequisite to functional activities (Figura, Cama, Capranica, Guidetti, & Pulejo, 1991; Shumway-Cook & Woollacott, 1985) and its failure can seriously limit performance and quality of live (Baker, Newstead, Mossberg, & Nicodemus, 1998).

The most current measures for assessing the postural sway are related to the excursion of the center of pressure (COP) (Hof, Gazendam, & Sinke, 2005; Prieto, Myklebust, Hoffmann, Lovett, & Myklebust, 1996), which has been widely used in the literature (Deitz, Richardson, Crowe, & Westcott, 1996; Murray, Seireg, & Sepic, 1975; Winter, 2009; Wrisley & Whitney, 2004). Several postural parameters (PPs) in the time and/or frequency domains have been reported according to the COP

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excursion (Cherng, Lee, & Su, 2003; Wolff et al., 1998). PPs in the time domain have been used extensively to quantify postural stability (Baloh et al., 1994; Ledin & Odkvist, 1993; McGraw, McClenaghan, Williams, Dickerson, & Ward, 2000). The main PPs of the COP excursion in this domain include: maximum displacement (range) both in anterior–posterior (A/P) and medial–lateral (M/L) directions, total length of its trajectory, sway area, and peak and average velocities (Abrahamova & Hlavacka, 2008; Galli et al., 2008). The range of COP displacement represents the difference between the maximum and minimum values; thus, it uses only two points that are thought to represent the changes occurring in an entire trial of data. But two points do not represent all changes occurring in a data sample (Palmieri, Ingersoll, Stone, & Krause, 2002). That is why the use of the range of COP displacement has been questioned and it is considered more appropriate to use the root mean square (RMS) of this displacement. The RMS of COP displacement measures the average absolute displacement around the mean COP and has been used by numerous researchers (Berg, Maki, Williams, Holliday, & Wood-Dauphinee, 1992; Geurts, Ribbers, Knoop, & van Limbeek, 1996; Niam, Cheung, Sullivan, Kent, & Gu, 1999). Palmieri et al. (2002) indicated that RMS and velocity of COP displacement are reliable measures to evaluate postural balance.

It is known that people with Down syndrome (DS) often show deficits in maintaining static standing balance, which has been considered as a partial explanation for the common functional balance problems in this population (Galli et al., 2008). Their condition generally leads them to be more inactive which contributes to an even worse postural control (Cabeza-Ruiz et al., 2011).

Studies in adolescents with DS have shown their precarious balance (Galli et al., 2008; Villarroya et al., 2012; Vuillerme, Marin, & Debû, 2001) and have indicated that although they have similar postural control strategies than adolescents without DS, they may present quantitative differences in the integration of sensory input to control stance (Vuillerme et al., 2001).

Adapted training programs could improve balance in these adolescents (Jankowicz-Szymanska, Mikolajczyk, & Wojtanowski, 2012). These programs, as indicated in previous studies, should pay attention on somatosensory input, but also in the motor system (strength and muscular coordination), responsible from executing coordinated musculoskeletal responses (Block, 1991; Davis & Kelso, 1982; Villarroya et al., 2012). Vibration therapy is one form of somatosensory stimulation that shows considerable promises for rehabilitation treatments (Filippi et al., 2009; González-Agüero, Matute-Llorente, Gómez-Cabello, Casajús, & Vicente-Rodríguez, 2013; van Nes, Geurts, Hendricks, & Duysens, 2004).

Whole body vibration (WBV) training exposes the entire body to mechanical vibrations as the individual stands on a platform that oscillates at a particular frequency and amplitude (Mahieu et al., 2006; Rees, Murphy, & Watsford, 2007). Vibration effects on the human body have been widely investigated. It has been described that vibration therapy produces an improvement of bone density and of functional performance (e.g. flexibility, strength, power, balance, etc.) (Bosco et al., 1998; Mani, Milosavljevic, & Sullivan, 2010; Mester, Kleinoder, & Yue, 2006; Rubin, Turner, Bain, Mallinckrodt, & McLeod, 2001, 2004; Torvinen et al., 2002a, 2002b; Totosy de Zepetnek, Giangregorio, & Craven, 2009; Verschueren et al., 2004; Wunderer, Schabrun, & Chipchase, 2010). Vibrations stimulate muscle spindles (Burke, Hagbarth, Lofstedt, & Wallin, 1976a, 1976b), activating muscles reflexes (Bogaerts et al., 2011; Burke & Schiller, 1976; Mahieu et al., 2006; Rees et al., 2007; Rittweger, Beller, & Felsenberg, 2000), which might implicate the improvement of contractile properties and strength of muscle and hence the balancing ability (Magnusson, Enbom, Johansson, & Wiklund, 1990; Rittweger, 2010).

Most of the authors have described an improvement of the balancing ability with WBV training (Bautmans, Van Hees, Lemper, & Mets, 2005; Bogaerts et al., 2011; Bruyere et al., 2005; Cheung et al., 2007; Kawanabe et al., 2007; Moezy, Olyaei, Hadian, Razi, & Faghihzadeh, 2008; Priplata, Niemi, Harry, Lipsitz, & Collins, 2003; Rees et al., 2007; Schuhfried, Mittermaier, Jovanovic, Pieber, & Paternostro-Sluga, 2005; van Nes et al., 2004, 2006; Verschueren et al., 2004), although others, as Torvinen et al. (2002a, 2002b, 2003) and Mahieu et al. (2006), did not find positive effects in the populations they studied. Probably, as Cheung et al. (2007) indicated, because they acted on young healthy people without a high improvement margin. Therefore, we hypothesized that WBV would enhance the altered balance of adolescents with DS, which, to our knowledge, has not been studied. The objective of this study was to investigate, with a randomized controlled trial, the effects of a 20-week WBV intervention on static balance in adolescents with DS and without DS.

2. Materials and methods

2.1. Participants

A sample of 30 children and adolescents (11 females/19 males aged 11–20 years) with DS were recruited from different schools and institutions of Aragón (Spain). An age- and sex-matched control group (CG) composed of 27 participants (9 females/18 males) without DS was also recruited. Inclusion criteria for the DS group (DSG) subjects were: the presence of trisomy 21; the absence of any gross visual or organic defect and independence in stance and ambulation. All participants without DS were healthy, without signs of any orthopedic or neurological disorders, impairment of somatosensory activity, hearing, vestibular or uncorrected visual functions and free of medications for at least 3 months before the beginning of the study. The recruited participants were randomly designated either to perform or not WBV training. Therefore, 4 groups were formed: participants who performed WBV training, in the CG (VCG) and in the DSG (VDSG), and participants who did not perform WBV training, in the CG (nVCG) and in the DSG (nVDSG).

Full clinical history, including illnesses or surgical interventions and stays in a hospital, was collected for all individuals. Both parents and children were informed about the aims and procedures, as well as possible risks and benefits, of the study.

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Table 1
Exercise protocol for the whole body vibration training.

	Sessions	Frequency (Hz)	Amplitude (mm)	Duration (s)	Rest (s)	Repetitions	Vibration total time (min)	Training total time (min)	Vibration dose (g)
Month 1	3	25	2	30	60	10	5	15	1.8
Month 2	3	28	2	30	60	10	5	15	2.2
Month 3	3	28	2	45	60	10	7.5	17.5	2.2
Month 4	3	28	2	45	60	10	7.5	17.5	2.2
Month 5	3	30	2	60	60	10	10	20	2.6

Written informed consent was obtained from all the subjects included and from their parents or guardians. The study was performed in accordance with the Helsinki Declaration of 1961 (revised in Edinburgh, 2000) and was approved by the Research Ethics Committee of the Government of Aragon (CEICA, Spain).

2.2. Procedure

The effect of 20-week WBV training on balance was evaluated, in a group of DS adolescents and in a CG, by means of the analysis of center of pressures (COP) displacements, at baseline and at the end of the study.

2.3. WBV training

The participants in the WBV groups exercised three times per week in a vertical vibration platform (Power Plate® Pro5; PowerPlate, Amsterdam, The Netherlands). The schedule of training is detailed in Table 1. Vertical platforms have shown a significantly larger treatment effect for chronic adaptations as compared with oscillating platforms (Marin & Rhea, 2010). A familiarization period of 3 sessions (1 week approximately) was conducted previous to any training with each participant. A researcher always accompanied the adolescents performing the training to ensure safety and to supervise a correct (knee angle) and complete (all sets) performance. Each training session was registered and any disease or nuisance annotated. The position on the platform was squat, due to its relative simplicity for adolescents with DS and because it has been showed effective in other populations (Von Stengel, Kemmler, Bebenek, Engelke, & Kalender, 2011, 2012), participants wear sport shoes during the trainings.

A minimum training attendance of 60% was demanded to be included in the WBV group; the data from those participants who did not meet this criteria were excluded from the posterior analyses.

2.4. Balance assessment

Balance of each participant was assessed at baseline and within the next fifteen days after the last WBV training, using a pressure distribution platform (Loran Engineering SrL, Italy. Software "FootChecker" 4.0.) with 2304 resistive sensors and a sampling frequency of 30 Hz, which allowed to collect COP displacement data. Subjects were instructed to maintain an upright standing position on the pressure platform, barefoot with arms hanging by the sides and feet positioned in a standardized position for stabilometric analysis (Kapteyn et al., 1983; Scoppa, Capra, Gallamini, & Shiffer, 2013) (forming 30° relative to each other and heels 5 cm apart) for 30 s. Each participant performed 2 trials under four balance testing conditions, generally used in clinical tests of sensory interaction on balance (Lin, Lee, Chen, Lee, & Kuo, 2006; Wrisley & Whitney, 2004). The conditions were: (C1) open-eyes, fixed-foot-support, (C2) closed-eyes, fixed-foot-support, (C3) open-eyes, compliant-foot-support, (C4) closed-eyes, compliant-foot-support. With open-eyes, subjects were asked to look at a 1.5 m-distant black target, adjustable in height according to the eye level of each subject. The pressure platform served as the fixed-foot-support. In the compliant-foot-support condition, a medium density foam mat was placed under the subjects' feet to alter somatosensory input. The order of trials with open or closed eyes was balanced among subjects to control any effects associated with repeated testing. One practice trial prior to testing was allowed to familiarize participants with the procedure. Standardized verbal cues of encouragement were given to each subject. Testing was conducted in a quiet room to limit external influences. The subjects were permitted to have short breaks between trials and between tests.

2.5. Variables

Independent variables were gender, condition (DS and non-DS) and training (WBV and non-WBV). Dependent variables were (1) postural parameters (PPs) frequently used in other studies (Isableu & Vuillerme, 2006; Palmieri et al., 2002; Vuillerme et al., 2001), based on COP sway and calculated using the raw data supplied by the system: RMS of COP excursion (RMS-ROM; mm) in the A/P and M/L directions and COP mean velocity (mean velocity; mm/s), under the four studied conditions related to vision and support, (2) ratios of these PPs among the four studied conditions, to evaluate the contribution of each sensory system influencing postural control, as previously described by Hirabayashi and Iwasaki (1995). These ratios were: (A) ratios between condition 2/condition 1 (C2/C1). They represent the effect of closing eyes on stability

Table 2
General features of the participants of both groups.

	Control group (*N*: 25)				*p*	Down Syndrome group (*N*: 29)				*p*
	Vibration *N* = 11		No vibration *N* = 14			Vibration *N* = 16		No vibration *N* = 13		
	Mean	sd	Mean	sd		Mean	sd	Mean	sd	
Age (years)	*14.53*	*2.67*	*15.40*	*1.81*	*0.343*	*15.93*	*2.48*	*15.64*	*2.93*	*0.771*
Weight (kg)	53.75	14.17	59.07	13.32	*0.326*	48.44	8.83	51.93	14.10	*0.417*
Height (cm)	159.50	13.86	166.00	12.04	*0.204*	148.75	8.16	147.57	12.61	*0.761*[*]
BMI (kg/m)	20.72	2.86	21.17	2.60	*0.676*	21.79	3.11	23.55	4.96	*0.248*

DS, Down syndrome; BMI, body mass index.
[*] *p*: 0.0001 between CG and DSG.

stance. (B) Ratios between condition 3/condition 1 (C3/C1). These ratios represent the effect of somatosensory input on the stability. (C) Ratios between condition4/condition 1 (C4/C1). These ratios represent the effect both of visual and somatosensory input on the stability stance.

For each of the mentioned variables and for each condition, the average of two trials was used in the statistical analysis.

2.6. Statistical analysis

In order to avoid the influence of the height, the RMS of COP excursions in the A/P and M/L directions were normalized to this variable (Chiari, Rocchi, & Cappello, 2002; Rigoldi, Galli, Mainardi, Crivellini, & Albertini, 2011). The SPSS 15.0 software for Windows (SPSS Inc., Chicago, IL) was used for the analyses and the significance level was 5%.

Mean and standard deviations were calculated for the description of dependent variables (by gender). All data were tested for normality by using the Kolmogorov–Smirnov test.

Dependent variables were compared at baseline between participants who performed and who did not perform WBV training (in CG and DSG), between boys and girls (in CG and DSG) and between the whole CG and the whole DSG, by using the independent *t*-test for normally distributed variables, and the Mann Whitney test for non-normal distributed variables.

The effects of the intervention were analyzed by repeated measures of ANOVA, followed by Bonferroni post hoc test.

3. Results

General features of participants are shown in Table 2.

As no differences between genders were found for any of the reported variables, results are shown as a group.

At baseline, no differences were found between groups who performed WBV and who did not, within each condition group.

Fig. 1 represents the comparison at baseline of mean values of the analyzed PPs between CG and DSG. All of them, under the four studied conditions related to vision and support, were greater in DSG with significant differences in most of them. Table 3 displays the comparison of mean values of the ratios of the analyzed PPs at baseline between CG and DSG. No differences between both groups were found except for ratios C3/C1 and C4/C1 of the mean velocity, which presented greater values in DSG than in CG.

Table 4 and Fig. 2 show means and standard deviations of analyzed PPs, under the four studied conditions, of the CG and DSG respectively at baseline and at the end of the study. In these tables, differences between these moments (baseline and the end of the study) both in the participants who performed WBV and in those who did not are indicated. No significant differences were found in any PPs in the CG and neither in the adolescents of the DSG who did not perform WBV but there were lower mean values in the analyzed PPs, with significant differences in RMS-ROM M/L and Mean Velocity, in those of the DSG who performed WBV under C4 (Fig. 2; both $p < 0.05$).

Comparison of the studied ratios between baseline and the end of the study showed a decrease in the ratio C4/C1 of the mean velocity in DS adolescents who perform WBV training (data not shown; $p < 0.05$).

4. Discussion

The present study analyzed the efficacy of WBV training on static balance in adolescents with DS. To our knowledge, this is the first investigation evaluating the effect of WBV training on balancing ability in people with DS. The findings show significant enhancement in stability in DS adolescents, with respect to M/L COP excursion and COP velocity, after the WBV intervention when vision and somatosensory input were altered.

4.1. Baseline features in both groups

DSG showed higher mean values of PPs than CG, under the four studied conditions, with significant differences mainly in the velocity of the COP displacement, which is considered a reliable parameter to assess balance (Palmieri et al., 2002);

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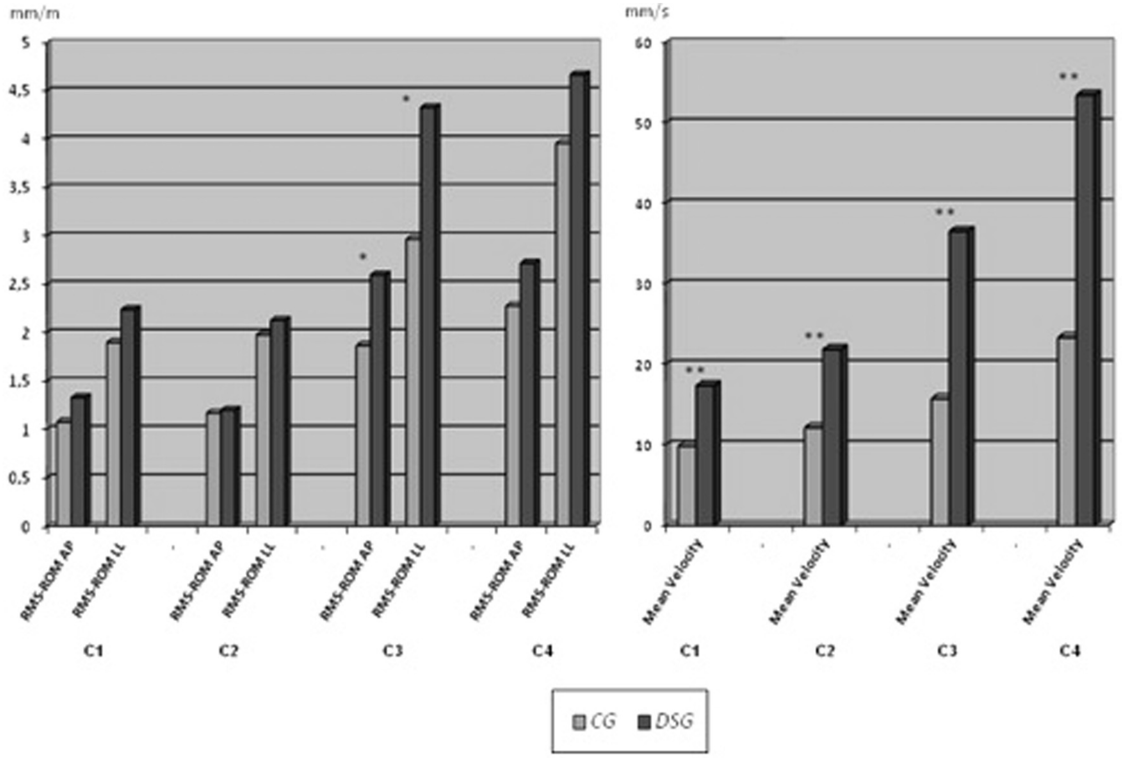

Fig. 1. Comparison of mean values of dependent variables between Control Group (CG) and Down Syndrome Group (DSG.); (C1, Condition1; C2, Condition2; C3, Condition3; C4, Condition4; RMS-ROM, root mean square of COP excursion; AP, anterior–posterior; ML, medial–lateral) *$p < 0.05$; **$p < 0.0001$.

therefore, as expected, DSG had worse balance than CG. The worse balance in DSG was more evident when somatosensory input was altered (C3 and C4). In fact, ratios C3/C1 and C4/C1 of the mean velocity were significantly greater in DSG (both in VDSG and in nVDSG), which shows that this population adapted worse to a decrease of this input. The worse balance in DS adolescents has been described also by other authors (Galli et al., 2008; Rigoldi et al., 2011; Villarroya et al., 2012; Vuillerme et al., 2001) and most of them insisted on the greater effort this population has to make to control balance under conditions of deteriorated somatosensory input (Shumway-Cook & Woollacott, 1985; Villarroya et al., 2012; Vuillerme et al., 2001; Woollacott, Debu, & Mowatt, 1987).

4.2. Effect of WBV

Different studies have analyzed the effect of WBV on balance (Bautmans et al., 2005; Bogaerts et al., 2011; Bruyere et al., 2005; Cheung et al., 2007; Kawanabe et al., 2007; Moezy et al., 2008; Priplata et al., 2003; Rees et al., 2007; Schuhfried et al., 2005; van Nes et al., 2004, 2006), but, to our knowledge, none of them has been carried out in DS population.

Table 3
Mean values and standard deviations of the ratios of the analyzed PPs at baseline in CG and DSG.

	Ratio C2/C1			Ratio C3/C1			Ratio C4/C1		
	CG	DSG	*p*	CG	DSG	*p*	CG	DSG	*p*
RMS-ROM AP (mm/m)									
Mean	23.27	11.55	*0.213*	153.74	183.85	*0.716*	181.96	167.86	*0.823*
SD	74.16	52.98		212.88	366.25		193.49	258.91	
RMS-ROM ML (mm/m)									
Mean	51.79	18.90	*0.119*	109.76	155.74	*0.277*	202.17	185.29	*0.750*
SD	86.57	67.00		109.37	185.18		225.69	157.60	
Mean velocity (mm/s)									
Mean	30.84	29.06	*0.827*	82.33	133.94	**0.044**	156.03	244.67	**0.039**
SD	28.75	31.24		66.74	110.19		87.99	196.00	

p: Signification of the comparison between control group (CG) and Down syndrome group (DSG). (C1, Condition1; C2, Condition2; C3, Condition3; C4, Condition4; RMS-ROM, root mean square of COP excursion; AP, anterior–posterior; ML, medial–lateral). Bold means statistically significant differences.

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Table 4
Mean values and standard deviations of dependent variables, under the four studied conditions, of the participants of the CG who not perform (nVCG) and who perform (VCG) WBV, at baseline and at the end of the study.

(A) nVCG	C1: FIX-SUP/OE			C2: FIX-SUP/CE			C3: COMP-SUP/OE			C4: COMP-SUP/CE		
	Pre	Post	*p*	Pre	Post	*p*	Pre	Post	*p*	Pre	Post	*p*
RMS-ROM AP (mm/m)												
Mean	1.24	1.28	*0.925*	1.38	1.18	*0.183*	1.87	1.84	*0.902*	2.40	2.48	*0.730*
SD	0.83	0.75		0.85	0.69		0.64	0.57		1.13	1.51	
RMS-ROM ML (mm/m)												
Mean	1.65	2.26	*0.064*	2.03	1.68	*0.074*	3.13	3.18	*0.923*	3.89	4.55	*0.345*
SD	0.89	1.29		0.90	0.94		1.39	1.71		1.63	2.02	
Mean velocity (mm/s)												
Mean	10.9	10.4	*0.320*	13.6	12.3	*0.183*	17.3	15.1	*0.109*	26.6	22.9	*0.056*
SD	6.2	5.8		5.4	7.0		3.9	03.8		9.8	4.3	

(B) VCG	C1: FIX-SUP/OE			C2: FIX-SUP/CE			C3: COMP-SUP/OE			C4: COMP-SUP/CE		
	Pre	Post	*p*	Pre	Post	*p*	Pre	Post	*p*	Pre	Post	*p*
RMS-ROM AP (mm/m)												
Mean	0.88	0.90	*0.865*	0.89	0.79	*0.091*	0.75	0.89	*0.540*	1.95	2.22	*0.424*
SD	0.44	0.62		0.63	0.82		0.85	0.96		1.38	2.16	
RMS-ROM ML (mm/m)												
Mean	1.90	1.50	*0.790*	1.88	1.63	*0.722*	2.67	2.31	*0.245*	3.70	3.36	*0.477*
SD	2.24	1.23		0.93	1.08		2.57	1.91		4.56	1.98	
Mean velocity (mm/s)												
Mean	8.0	7.7	*0.523*	9.5	8.6	*0.180*	13.7	12.7	*0.075*	18.3	18.4	*0.933*
SD	3.4	3.0		3.1	3.8		5.0	5.3		8.5	6.3	

p: Signification of the comparison between baseline (pre) and the end of the study (post) (FIX-SUP, fixed-foot-support; COMP-SUP, compliant-foot-support; OE, open-eyes; CE, closed-eyes; RMS-ROM, root mean square of COP excursion; AP, anterior–posterior; ML, medial–lateral).

In the present study, as expected, no differences in any of the studied variables were found at the end of the study in the adolescents who did not perform WBV training neither in DSG nor in CG.

Those in the VCG had no changes after the WBV training, which is in agreement with the studies of Torvinen et al. (2002a, 2002b, 2003) and Mahieu et al. (2006) who showed that WBV training produced no effect on the balance of their participants. There are, however, discrepancies in the effect of WBV as other studies showed positive effects on balance. Cheung et al. (2007) explained these discrepancies by differences in target subjects; in most of the studies with positive effects target subjects were people with balance problems (elderly people – Priplata et al., 2003; Kawanabe et al., 2007; Rees et al., 2007; Bogaerts et al., 2011; reconstruction of anterior cruciate ligament – Moezy et al., 2008; unilateral chronic stroke – van Nes et al., 2004, 2006; postmenopausial women – Verschueren et al., 2004; multiple sclerosis – Schuhfried et al., 2005; Wunderer et al., 2010), while studies without positive effects were carried out in healthy populations (Cheung et al., 2007; Mahieu et al., 2006; Torvinen et al., 2002a, 2002b, 2003). Mahieu et al. (2006) also speculated that WBV training only has a positive significant effect when the postural control of the subjects was disturbed. Therefore, healthy subjects might not readily gain additional benefits from WBV training (Cheung et al., 2007). Also the intensity of the WBV training and/or the duration might be influencing this lack of differences after the training. Maybe longer or more intense trainings could help also healthy adolescents to achieve better balance parameters.

However, the VDSG, with clear problems on its balance was a possible beneficiary of WBV training. This training had positive effects in the adolescents of this group although only under the worse studied condition, C4, with vision and somatosensory input altered. In this case, overall mean values of the PPs were lower than at baseline with significant differences in M/L COP excursion and COP velocity. As explained above, at baseline DS adolescents deal with the decrease of somatosensory information worse than those of the CG. The improvement of VDSG under this condition was confirmed when comparing ratios before and at the end of the training period; there was a significant decrease of ratio C4/C1 of the velocity in this group. This ratio, at baseline, was increased in adolescents of DSG related to those of the CG.

Vibration has been said to be one of the strongest methods for stimulating propioception (Priplata et al., 2003; Wierzbicka, Gilhodes, & Roll, 1998), and DS population, as described previously (Villarroya et al., 2012; Vuillerme et al., 2001), could greatly benefit from this stimulation. Gomes and Barela (2007) found that when additional sensory information was provided to their group of DS subjects, they took a great advantage of it decreasing body sway.

As above mentioned most of the authors showed positive effects of WBV in people with problems in balance although with important differences in their results (Bautmans et al., 2005; Bruyere et al., 2005; Cheung et al., 2007; Kawanabe et al., 2007; Moezy et al., 2008; Priplata et al., 2003; Rees et al., 2007; Schuhfried et al., 2005; van Nes et al., 2004, 2006; Verschueren et al., 2004). These differences may be due to the diversity of employed WBV training protocols which makes comparing results extremely difficult (Rees et al., 2007). This suggests the possibility that other programs could be more efficient than the one used in this work.

As Fagnani, Giombini, Di Cesare, Pigozzi, and Di Salvo (2006) indicated, the research within these areas is in its infancy. Future research about the optimal frequencies, amplitudes, durations and the number of sessions per week is necessary.

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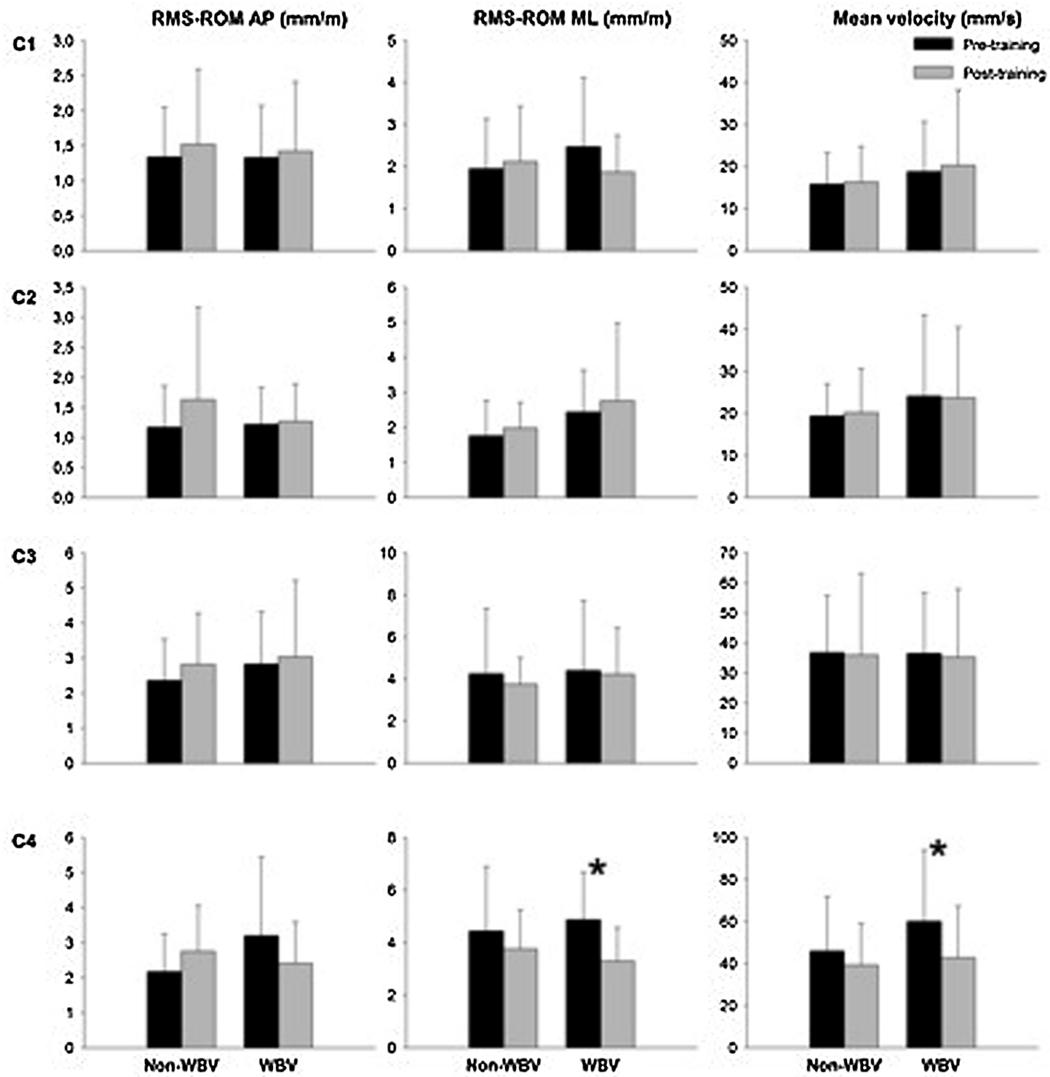

Fig. 2. Mean values and standard deviations of dependent variables, under the four studied conditions, of the participants of the DSG who not perform (nVDSG) and who perform (VDSG) WBV, at baseline and at the end of the study. *Signification of the comparison between baseline (pre-training) and the end of the study (post-training) < 0.05; (C1, Condition1; C2, Condition2; C3, Condition3; C4, Condition4; RMS-ROM, root mean square of COP excursion; AP, anterior–posterior; ML, medial–lateral).

The positive results of this study, although only under particular conditions, are encouraging. It is known that balance is essential for the upright posture and for most of the functional activities (Tanaka, Takeda, Izumi, Ino, & Ifukube, 1997) and that a postural instability can seriously limit them. Thus, the obtained results are promising for this special population with postural and performance limitations.

This study is not exempt of limitations. To control the efficacy of the vibration itself, avoiding the effect of the squat exercise, it had been optimal that the control group had performed squat exercise over a switched-off platform the same time than the WBV group; unfortunately they did not. Another limitation of the study was not to carry out a follow-up to verify how long the positive effects lasted.

Otherwise, the strengths of our study are the inclusion of both genders in the design and the use of a medically certificated device to train with this specific population.

Conflicts of interest

There are no conflicts of interest or financial disclosures for any author of this manuscript. None of the authors have any financial interest.

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